

What is claimed is:

1. An image pickup unit for picking up magnified images of an object, comprising:
an objective optical system having an image scale factor with an absolute value greater than unity and an image pickup surface,
wherein
the objective optical system includes, in order from the object side, a front lens unit having positive refractive power and an aperture stop having an opening, and
the objective optical system satisfies the following conditions

$$0.9 \leq |\cos w y' / \cos w y| \leq 1.1$$

$$0.2 \leq \Phi 1 / (\Phi 2 \cdot f 1) \leq 2$$

where

- wy' is the angle at which the chief ray corresponding to the largest half-field angle is incident onto the image pickup surface,
- wy is the half-field angle of a ray incident onto the image pickup surface,
- $\Phi 1$ is the diameter of the opening of the aperture stop,
- $\Phi 2$ is the largest outer diameter of the objective optical system, and
- f1 is the focal length of the front lens unit.

2. An image pickup unit for picking up magnified images of an object, comprising:
an objective optical system having an image scale factor with an absolute value greater than unity and an image pickup element, wherein the following condition is satisfied

$$0.1 \leq |p \cdot NA^2 / (0.61 \cdot \lambda \cdot \beta_0)| \leq 0.8$$

where

- p is the pixel size of the image pickup element,
- NA is the numerical aperture,
- λ is the wavelength at the e-line (546.1 nm), and
- β_0 is the image scale factor of the objective optical system.

1 3. A focus adjustment method for an image pickup unit that is provided with an objective
2 optical system having an image scale factor with an absolute value greater than unity and an
3 image pickup element, said method comprising the steps of:

4 (a) fixing a contrast chart at a predetermined distance from the object-side leading surface
5 of the objective optical system;

6 (b) moving the image pickup element along an optical axis of the objective optical system
7 and detecting two positions at which an image of the contrast chart that is formed on the image
8 pickup surface of the image pickup element has a predetermined contrast value; and

9 (c) based on said two positions, obtaining the position of the image pickup element at
10 which the image will have the highest contrast.

1 4. A focus adjustment apparatus for an image pickup unit that includes an objective optical
2 system having an image scale factor with an absolute value greater than unity and an image
3 pickup element, said focus adjustment apparatus comprising:

4 an object supporting part capable of supporting an object at a specified distance from the
5 object-side leading surface of the objective optical system;

6 a movable stage having a support member for fixing the image pickup element on the
7 moveable stage, said movable stage being movable along the optical axis of the objective optical
8 system at least between two positions where two images formed on the image pickup surface of
9 the image pickup element by the objective optical system have a predetermined contrast value;
10 and

11 a processing unit which calculates the contrast of images formed on the image pickup
12 surface and detects the two positions of the image pickup element at which the object image has
13 the predetermined contrast value, and using these two detected positions, calculates the position
14 of the image pickup surface at which the object image has the largest contrast.

1 5. A method of determining the range of focus for an image pickup unit that includes an
2 objective optical system having an image scale factor with an absolute value greater than unity
3 and an image pickup element, said method comprising the following steps:

4 (a) making a contrast chart object contact with the object-side leading surface of the
5 objective optical system;

6 (b) moving the contrast chart object along the optical axis of the objective optical system
7 until images formed on an image pickup surface of the image pickup element have a
8 predetermined contrast value; and

9 (c) detecting the position of the contrast chart along the optical axis where the
10 predetermined contrast value is achieved.

1 6. An apparatus for determining the range of focus for an image pickup unit that includes an
2 objective optical system having an image scale factor with an absolute value greater than unity
3 and an image pickup element, said apparatus comprising:

4 a first stage having a support member for supporting the image pickup unit ;

5 a second stage having a support member for supporting an object, said second stage being
6 movable at least between a position where the object contacts the object-side leading surface of
7 the objective optical system and a position where an image of the object formed on an image
8 pickup surface of the image pickup element by the objective optical system has a predetermined
9 contrast value; and

10 a detector that is capable of detecting the position of said object along the optical axis.

1 7. The image pickup unit according to claim 1, wherein:

2 the objective optical system comprises, in order from the object side, the front lens unit,
3 the aperture stop, and a rear lens unit having positive refractive power, and

4 the following condition is satisfied

5
$$2 \leq f2 / f1 \leq 10$$

6 where

7 f2 is the focal length of the rear lens unit, and

8 f1 is the focal length of the front lens unit.

1 8. The image pickup unit according to claim 2, wherein:

2 the objective optical system includes, in order from the object side, a front unit having
3 positive refractive power, an aperture stop and a rear unit having positive refractive power, and

the following condition is satisfied

$$2 \leq f_2 / f_1 \leq 10$$

where

f_2 is the focal length of the rear unit, and

f_1 is the focal length of the front unit.

9. The focus adjustment method according to claim 3, wherein:

in step (a), the distance from the objective lens to said two positions is measured with a precision of sub-microns.

10. The focus adjustment method according to claim 3, wherein:

in step (a), the position of the contrast chart object is set with an accuracy of within 1 micron by using a spacer between the objective optical system and the contrast chart object.

11. The focus adjustment method according to claim 3, and further comprising the following step:

detecting tilt of the object using interference fringes formed by interference between light reflected from the object and light reflected from the object side leading surface of the objective optical system; and

determining a reference position of the object for focus adjustment.

12. A focus adjustment apparatus for an image pickup unit that includes an objective optical system having an image scale factor with an absolute value greater than unity and an image pickup element, said focus adjustment apparatus comprising:

means for fixing an object at a specified distance from the object-side leading surface of the objective optical system;

means for moving the image pickup element along the optical axis of the objective optical system at least between two positions where two images formed on the image pickup surface of the image pickup element by the objective optical system have a predetermined contrast value; and

10 means for calculating the contrast of images formed on the image pickup surface and
11 detects the two positions of the image pickup element at which the object image has the
12 predetermined contrast value, and using these two detected positions, calculating the position of
13 the image pickup surface at which the object image has the largest contrast.

1 13. An apparatus for determining the range of focus for an image pickup unit that includes an
2 objective optical system having an image scale factor with an absolute value greater than unity
3 and an image pickup element, said apparatus comprising:

4 means for supporting the image pickup unit;

5 means for supporting an object and for moving the object at least between a position
6 where the object contacts the object-side leading surface of the objective optical system and a
7 position where an image of the object formed on an image pickup surface of the image pickup
8 element by the objective optical system has a predetermined contrast value; and

9 means for detecting the position of said object along the optical axis.